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Abstract (cont)

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An important pillar of the new procedure is a cumulative cost curve, generated from the provisioning costs of a small percentage of the total components, from which extrapolations are made of the total provisioning costs for the system. Selection of critical components is made by ranking parts by replacements per 100 end items x component unit price.

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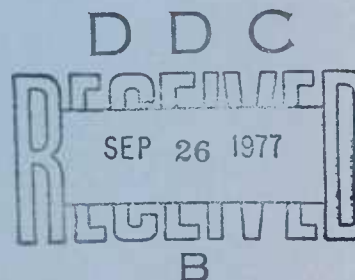
**BARE BONES : A METHOD FOR ESTIMATING
PROVISIONING BUDGET REQUIREMENTS
IN THE OUTYEARS**



**U.S. ARMY
I N V E N T O R Y
R E S E A R C H
O F F I C E**

JULY 1977

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BARE BONES: A METHOD FOR ESTIMATING PROVISIONING BUDGET
REQUIREMENTS IN THE OUTYEARS

FINAL REPORT

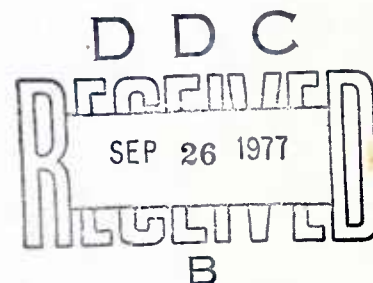
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JULY 1977

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SUMMARY

Different methodologies and procedures are currently used by Project Managers/Commodity Commands in the Army to estimate initial provisioning funding requirements early in the development cycle of a system/end item. These estimates are to project support costs 1-5 years hence; the lack of quality, uniform methodology, and defensible rationale in the estimates have concerned the Department of the Army.

Cost Estimating Relations and historical planning factors for relating provisioning costs to other variables of the end item are deemed of limited value, particularly with pending changes in the Army computational procedures for determining provisioning quantities (Standard Initial Provisioning Model - SIP). A prototype methodology is developed that reflects, early on, the quantities and costs that would be determined ultimately using SIP just prior to the deployment of the end item in the budget execution year.

This "Bare-Bones" SIP strips the computational procedure down to its essential formulae, which can be "run" off-line or manually. Estimates of 9-10 critical parameters for major components are needed; initially these estimates are obtained from similar components and subsystems in similar older systems; the values are suitably modified and cost projections refined as more information becomes available, later in the life cycle.

An important pillar of the new procedure is a cumulative cost curve, generated from the provisioning costs of a small percentage of the total components, from which extrapolations are made of the total provisioning costs for the system. Selection of critical components is made by ranking parts by replacements per 100 end items x component unit price.

Usefulness of cost curves for extrapolating was tested on two systems - one of which had limited data on only 13 major components of the end item, but which still yielded a reasonable curve for projecting provisioning costs.

PREFACE

THE CREATION OF BARE-BONES

The following chapters and appendices are an end result and describe an end result - a budget tool to determine provisioning funding requirements one to five years prior to end item deployment. However, their contents do not indicate the thought processes which led to the approach taken. Pedagogically a synopsis of the constraints and issues surrounding the problem and of the solutions sought should be enlightening.

The Situation: The Army is presently implementing new policy and computational procedures with regard to initial provisioning; a Standard Initial Provisioning (SIP) model is to be incorporated into the CCSS and interface with its file structure. Automated computation via SIP to determine actual provisioning buys requires loading of files, utilizing latest refined estimates of item parameters. For various budget reviews prior to actual SIP runs, projections of necessary provisioning funding are required. DA and OSD have been concerned with the lack of quality, uniform methodology, and defensible rationale for the projections at previous budget reviews.

The Problem: Estimates of initial provisioning outyear funding requirements are needed. Present procedures are inadequate: estimates are generally inaccurate; there are communication problems due to lack of a standard procedure; estimates do not reflect quantities and costs that would be determined by SIP; there are no systematic and smooth procedures for transition to actual SIP computations.

We were aware of costing approaches in use by the Services and of existing methods of potential use.

- a. Subjective; Expert Judgement; DELPHI - quantification of a set of guesstimates.
- b. Historical Ratios - widely used, typically by using the percentage of provisioning cost to acquisition cost for a similar system.
- c. Cost Estimating Relations (CER's); Planning factors - historical data is used to relate costs to such system variables as speed, power output, reliability.

d. Pipeline - failures method - number of failures over a required pipeline time determines the support quantity of a component.

e. Parameter File - Cost Support Model method - in the present case, this involves a full scale run of the SIP program.

Once it was realized consciously that SIP would be the main tool later in the life cycle of the system/end item to determine actual provisioning buys, and that one is not predicting from established or standard quantities and costs, but what will be determined via SIP, our choices narrowed considerably. A mirror into the past would not be a good reflection of the future in this case of changing procedures; in any case a massive historical data collection was to be avoided due to the time frame of the project. Hence we wished to find some compromise between the oversimplification of d. and the over-sophistication (and stringent input requirements) of e. We felt the historical onus (when necessary) should be placed on component parameter estimates (subsequently massaged by our compromise model), rather than on aggregated system costs (heuristically massaged by new policy).

Consequently "Bare-Bones" SIP was born. It strips the computational procedure down to its essential formulae. Estimates of 9-10 critical parameters for major components are needed; initially these estimates are obtained from similar components in older systems and the values are refined (or replaced with test results), later in the life cycle.

One had to consider only "major" components, facing the reality of data availability early in the life cycle. The problem was how to translate these component provisioning costs into a projection of total provisioning cost for the end item/system. It was felt a cumulative cost curve might be successful since a few components often constitute a major part of the support costs. A question remained of how to rank components for the selection process; the test results indicate that our first intuitive choice, maintenance factor x unit price was a good one.

The test results are more fully discussed in Appendix A.5^{*}. It was

* During the implementation phase, a comparison of BBSIP quantities and costs to actual SIP values on the TOW-COBRA missile-helicopter system yielded very close agreement.

found the cumulative costs started to level off after a small percentage of the system components were plotted and that good projections of total costs could be made. The approach was one of experimentation; several types of graph paper were tried and several ranking measures were used in plotting points. Heuristics were developed for curve-fitting and extrapolation by hand and eye. Computerized line fitting routines were rejected because of inflexibility and stringency of assumptions and point-curve error measures.

Other Services could utilize this same approach, where Bare-Bones SIP represents the bare-bones of their particular provisioning procedure (which must also adhere to DoDI 4140.42).

Some perspective on the bare-bones method is shown in the following table.

ADVANTAGES

1. "Simulates" SIP without the details. Softens the input requirements of SIP.
2. Not dependent on past data (with a few exceptions) to build models or relationships.
3. Not critical to verify procedure on past systems' data.
4. Adaptable to changes in density projections for high density situations.
5. Provides smooth transition to the routine provisioning phase using SIP computations.

DISADVANTAGES

1. The percent of all reparable required to be "run" is unknown initially.
2. An estimated piece part gross repair cost by echelon is needed in many cases. (for non-APA)
3. Special provisioning concepts have to be handled by special procedures.
4. For low density situations, changes in program necessitate overall computations.
5. Important to have accurate input for critical spares. (Holds in general for other approaches.)

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CHAPTER I

INTRODUCTION

1.1 Standard Initial Provisioning (SIP) Program vs Bare Bones SIP (BBSIP)

Bare Bones SIP is a budget tool to determine funding requirements by end item/systems one to five years before the execution year (when actual buys are made to provision a newly fielded system). Figure 1.1 summarizes the purposes and comparisons of SIP vs BBSIP, from which the necessity of such a tool is apparent.

The usefulness of Bare Bones SIP as a manual or off-line computerized procedure lies in the simplicity of its computational procedures which in turn rely on some sensible approximations. The major approximations to special features of SIP, which adhere to DoDI 4140.42, are listed in Figure 1.2.

1.2 Bare Bones SIP Procedure

The procedure is outlined in Figure 1.3 with exemplification in Figures 1.4 and 1.5. The BBSIP provisioning cost estimating methodology is most useful and beneficial in determining APA funding requirements, and the procedural and computational details of Chapters II and III emphasize this aspect.

Figure 1.6 represents the logic flow.

Time Phasing, Yearly Requirements, and Sequential Use of Bare Bones SIP:

The quantity and cost requirements of the components addressed by the BBSIP are keyed to the end item density in the program forecast period (usually the procurement lead time + 3 months). The analyst determines at what time what portion of the total quantity of a component is to be bought based on contractual requirements and lead times of the item components. This will determine a yearly requirement. A subsequent BBSIP "run" with improved input parameter estimates will yield a more refined total cost requirement, from which will be subtracted the previously planned or actual procurement costs to obtain a remaining requirement (both for a specific component and for cumulative provisioning costs over all components).

BBSIP runs for budget reviews very early in the development cycle are used to project total provisioning budget requirements for the end item/system. BBSIP runs for later budget reviews (but prior to actual SIP program runs on particular components) are disaggregated in the above manner for component and yearly requirements.

SIP

BARE BONES SIP

• COMPUTATIONAL PROCEDURES SATISFYING .42

• APPROXIMATES PROCEDURE; BASIC FORMULAS; FEWER INPUT PARAMETERS

• PURPOSE: TO DETERMINE BUYS (EXECUTION YEAR)
BY ITEM

• PURPOSE: TO PROJECT AGGREGATED BUDGET REQUIREMENTS
IN OUTYEARS

DESIGNED TO PURPOSE

• ALL ITEMS, CODED

• SMALL % OF COMPONENTS

• LATEST REFINED INPUTS

• BEST CURRENTLY AVAILABLE INPUTS (EARLY)

• INTERFACED WITH CCSS FILES, PMDR NSNMDR, ETC.
AND WITH RD&E SYSTEM

• SHORT PROGRAM, OFF LINE

INAPPLICABILITY TO CROSS PURPOSE

BUDGET

BUYS

• EXPENSIVE

• CANNOT DETAIL BUYS BY AREA, BY PHASES

• INACCURACY OF EARLY PARAMETER ESTIMATES
OVERRIDES SOPHISTICATED PROCEDURE
VS BBSIP

• IS NOT LINKED TO FILES TO PROVIDE COMPLETE
PROVISIONING OUTPUT

• CONTINUAL RELOADING OF PMDR

• DOES NOT COMPUTE ACTUAL QUANTITIES FOR PIECEPARTS

FIGURE 1.1 PURPOSES SIP VS BBSIP

SIP

SPECIAL FEATURES

- "COSDIF" - ECONOMICAL TO STOCK QUESTION
- PHASED PROVISIONING
- DEPLOYMENT SCHEDULE
- AREA DIFFERENCES
- ERPSL METHODOLOGY

BBSIP

APPROXIMATIONS

- ASSUMES HIGHLY RANKED COMPONENTS STOCKED
- TOTAL COST OVER A PLANNING HORIZON
- AN AVERAGE PROGRAM DENSITY
- AVG PARAMETERS ACROSS AREAS
- BASIC FORMULA

FIGURE 1.2 BBSIP APPROXIMATIONS

OVERVIEW OF BASIC METHOD

REPARABLES (AND SOME EXPENSIVE NON REPS) ARE RANKED BY THE MEASURE $MF \times UP$.

10 COMPUTE QUANTITY AND COST OF SPARES REQUIRED BY USING "BARE BONES" SIP FORMULAE. CONSIDERS MAJOR DATA ELEMENTS AND THE BEST AVAILABLE PARAMETER ESTIMATES AT THE TIME.

CUMULATIVE COSTS PLOTTED VS RANKING MEASURE. PROCESS STOPS WHEN THE ACCUMULATED PROVISIONING COST IS SOME APPRECIABLE % OF THE EXTRAPOLATED TOTAL COST.

FIGURE 1.3

<u>RANKED COMPONENT</u>	<u>MF X UP</u>	<u>PROVISIONING COST</u>	<u>CUMULATIVE COST</u>
#1	50 x 5000 (250,000)	\$ 180,000	\$ 180,000
#2	40 x 800 (32,000)	12,000	192,000
#3	25 x 800 (20,000)	10,000	202,000
I #4	15 x 600 (9000)	8000	210,000

FIGURE 1.4 EXAMPLE VALUES

COST CURVE

CUMULATIVE
PROVISIONING
COST

EXTRAPOLATED TOTAL PROVISIONING COST REQUIREMENT

STOP?

$1/(MF \times UP)$

SPARE #1

SPARE #1
+ #2

FIGURE 1.5

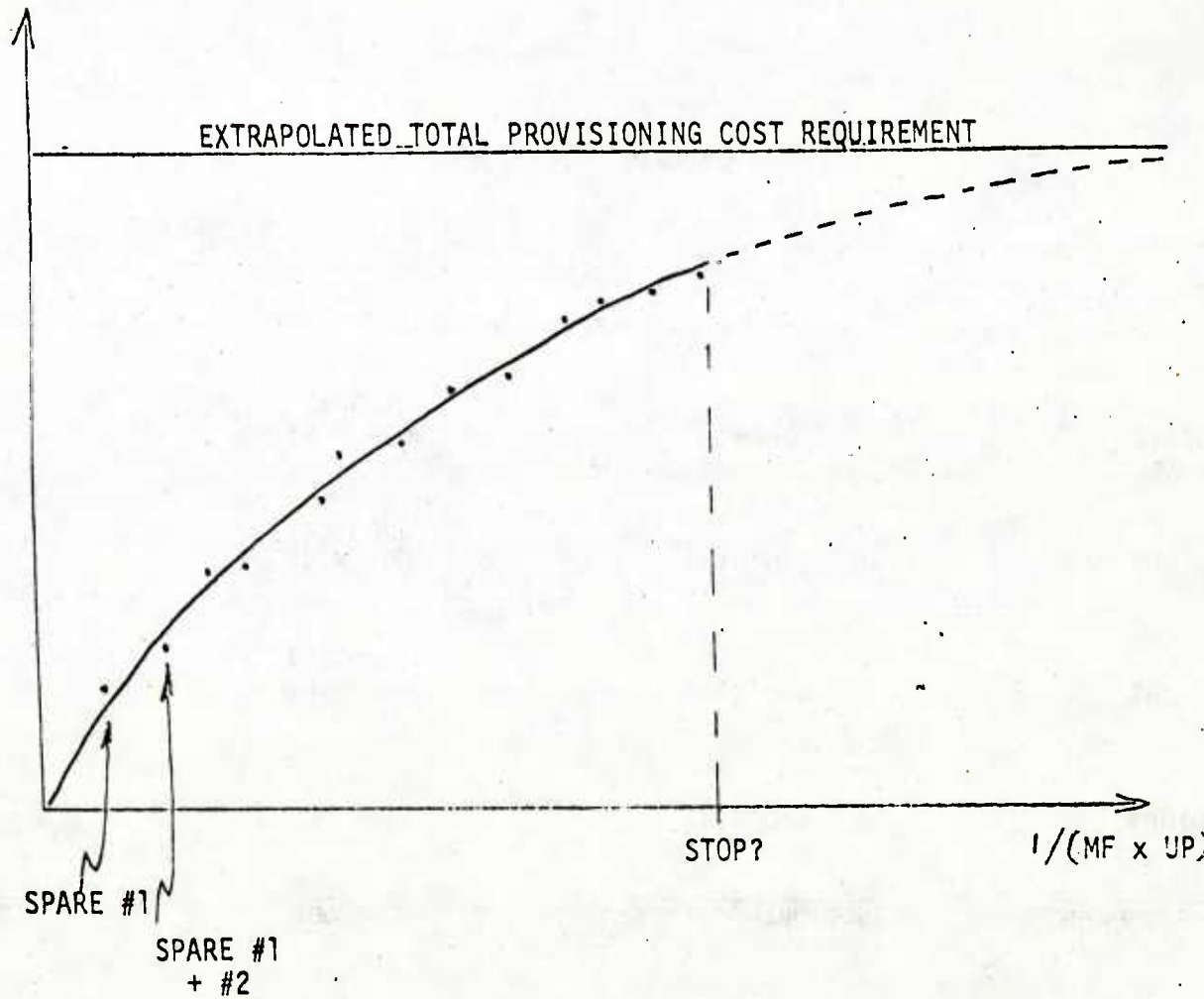
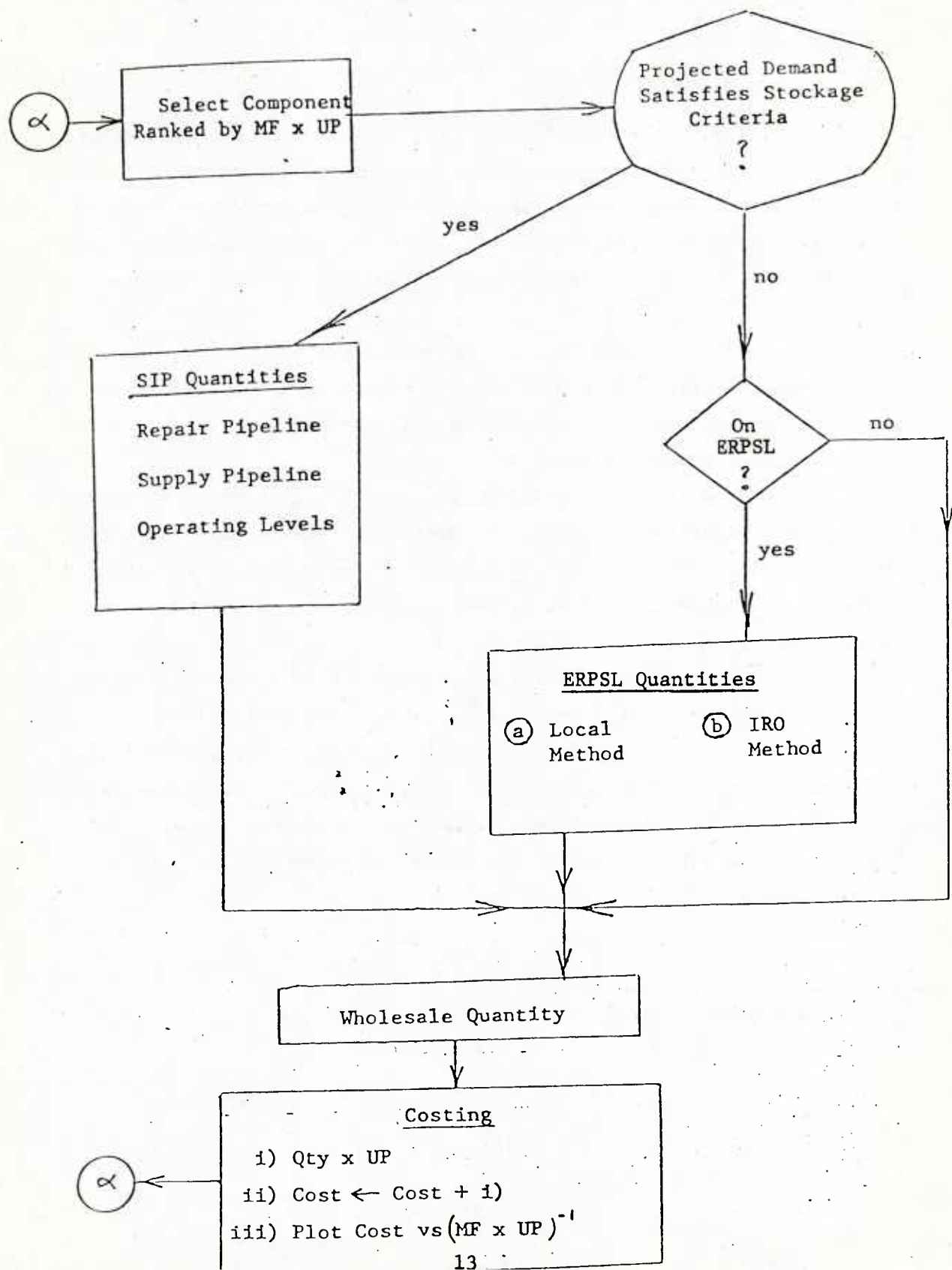


FIGURE 1.6
BARE BONES SIP LOGIC FLOW



CHAPTER II

DETERMINATION OF REQUIRED QUANTITY OF AN APA COMPONENT

2.1 Input Parameters

2.1.1 Guidelines

The data elements in 2.1.2 are required for each APA component on which BBSIP is to be run. How these parameter estimates are to be obtained at various stages of the conceptual and developmental phases of an end item/system is indicated by the following guidelines. Each reflects points in time with particular degrees of availability and refinement of data.

a. Choose systems and subsystems most similar to proposed system. Use parameter (both hardware and maintenance support) values of the generic components therein. Adjust only for planned system density and inflation of component costs.

b. As in (a), but adjust for planned or targeted improvements in component reliability. Adjust for gross maintenance support concept (where to replace, where to repair, number of supporting stock points).

c. Phase in actual components and their planned design characteristics, when identified.

d. As in (c), utilizing contractor and/or test estimates of component unit price and replacement rates, when available.

e. Utilize LSA^{*} in an iterative fashion in conjunction with prototype test results and subsequent design changes to determine refined estimates of hardware and maintenance support parameters of major components. Use latest information on planned deployment density in the budgeted years.

^{*} Logistics Support Analysis

2.1.2 Description of Data Elements

The following are worldwide averages.* Appendix A.2 describes refinements to BBSIP if it is desired to account for area differences (e.g., CONUS, Overseas).

<u>DATA ELEMENT</u>	<u>DESCRIPTION</u>
MF	Maintenance factor (replacements per year/100 end items)
UP	Unit price of one component
U	% of component (if reparable) washed out (condemned)

For all support echelons J, e.g., ORG, DSU, GSU, Depot

V(J)	% of replacements made at echelon J, $\sum V(J) = 100\%$
P(J)	% of repairs made at echelon J
	$U + \sum P(J) = 100\%$
TAT(J)	Turn-around-time at echelon J. Time required to repair the component (fraction of a year)
OST(J)	Order & shipping time between stockpoint J and applicable supporting stockpoint (fraction of a year). This value usually does not vary by type of spare; past averages or required times may be given.

Next parameters are needed only for the end item

PD	Program Density - number of end items to be deployed in the program forecast period (PFP) (period for which initial provisioning requirement is made). PFP = Procurement Lead Time + 3 months
M(J)	# Supporting Stock Points at echelon J

*For elements PD, M(J), the values are to be worldwide totals.

2.2 Formulas and Logic Flow

- a. Select next APA component ranked by MF x UP.
- b. Determine echelons in the support concept

J = 2 is organizational level

Highest J (e.g. J = 6) is CONUS Wholesale Depot

- c.* Compute VSUM(J) and PSUM(J) for all echelons

$$\text{VSUM}(J) = \sum_{k=2}^J V(k)$$

$$\text{PSUM}(J) = \sum_{k=2}^J P(k)$$

Check: PSUM(6) + U = VSUM(6) = 1.00

- d. Retail Stockage Criteria Checks for J = 2,3,4,5,
maybe fewer

Compute

$$R(J) = \left(\frac{MF}{100} \right) \times (\text{VSUM}(J) - \text{PSUM}(J-1)) \times \frac{FD}{M(I)}$$

If component is non-ERPSL:

Is R(J) less than 6? **

If no, go to step (e)

If component is ERPSL (DA approves ERPSL for end item): ***

If V(J) is at least .50, go to step (f)

If V(J) is less than .50, go to step (e)

* If component is a nonreparable, P(J) = 0, U = 1.00.

** Criterion other than 6 may be used, based on actual criterion used in field.

*** As of Aug '77, all non demand supported components (R(J) < 6 when V(J) > .50) were made "ERPSL" components for budget computations.

e. Retail Pipeline & Operating Level Quantities

Repair Pipeline quantity $Q_1(J)$

$$P(J) \times TAT(J) \times \frac{MF}{100} \times PD$$

Supply Pipeline quantity $Q_2(J)$

$$(VSUM(J) - PSUM(J)) \times OST(J) \times \frac{MF}{100} \times PD$$

Operating Level quantity $Q_{OL}(J)$

$$\text{If } [(VSUM(J) - PSUM(J)) \times \frac{30}{360} \times \frac{MF}{100} \times \frac{PD}{M(J)}]$$

is greater than 0.5, $Q_{OL}(J) = M(J)$

Otherwise $Q_{OL}(J) = 0$

Return to step (d) for next retail echelon J, if any. Otherwise go to step (g).

f. ERPSL Computation (To be done only if system qualifies and if this component is essential)

$$\text{Compute } \lambda = \frac{MF}{100} \times \frac{PD}{M(J)} \times [(VSUM(J) - PSUM(J)) \times OST(J) + P(J) \times TAT(J)]$$

Determine unit price of next higher assembly UP_{NHA} .

(In many cases, for APA components, this would be the price of the end item)

Compute $A = 1 - UP/UP_{NHA}$, but constrain A to be at least .95 and no more than .99.

Find the smallest $Q'_E(J)$ such that

$$\left[\sum_{i=0}^{Q'_E} e^{-\lambda} \frac{\lambda^i}{i!} \right] \text{ is greater than } A$$

or use Cumulative Poisson tables.

$$Q_E(J) = Q'_E \times M(J)$$

Return to step (d) for next retail echelon J, if any.

Otherwise go to step (g)

g. Wholesale Depot computation and consolidation

Wholesale quantity q:

$$q = \frac{MF}{100} \times U \times \frac{PD}{2}$$

Wholesale Depot repair quantity:

$$Q_1(6) = P(6) \times TAT(6) \times \frac{MF}{100} \times PD$$

Consolidation: Sum up all non-zero quantities

$$q + Q_1(6) + \sum_2^5 Q_1(J) + Q_2(J) + Q_{OL}(J) + Q_E(J) \equiv Q$$

CHAPTER III

DETERMINATION OF PROVISIONING COSTS OF APA COMPONENTS

3.1 Ranking & Plotting

- a. Identify as many APA subsystems, assemblies, components of the end item as possible and for which parameter estimates of some reasonableness are currently available.
- b. Rank these components by the estimated values of $MF \times UP$ in descending order.
- c. Select the next highest ranked component n and apply the BBSIP computational procedure of Section 2.2 to determine the provisioning quantity
- d. Determine the component provisioning cost $C_n = Q \times UP$
- e. Add C_n to any previous cumulative cost, C , i.e.

$$C_n = C_{n-1} + C_n$$

- f. Plot the new cumulative cost C_n versus $1/(MF \times UP)$ on log-log paper (see below)
- g. Any components remaining? If yes, go to step (c)
- h. Can an extrapolation or estimate of total APA costs be made? (See Section 3.2)
If no, go to step (a) and identify more components, relying on most similar end item/systems if necessary.
- i. Stop. Record estimated total APA provisioning cost for this system.

Comment: Typical 3 cycle by 3 cycle log-log graph paper is shown in Figure 3.1 with some sample points plotted. Equal intervals on the scales differ by factors of 10. One is thereby representing the logarithms of the \bar{c} and $1/(\text{MF} \times \text{UP})$ values. This representation is found necessary due to the wide range of cumulative cost and $\text{MF} \times \text{UP}$ values that will be encountered.

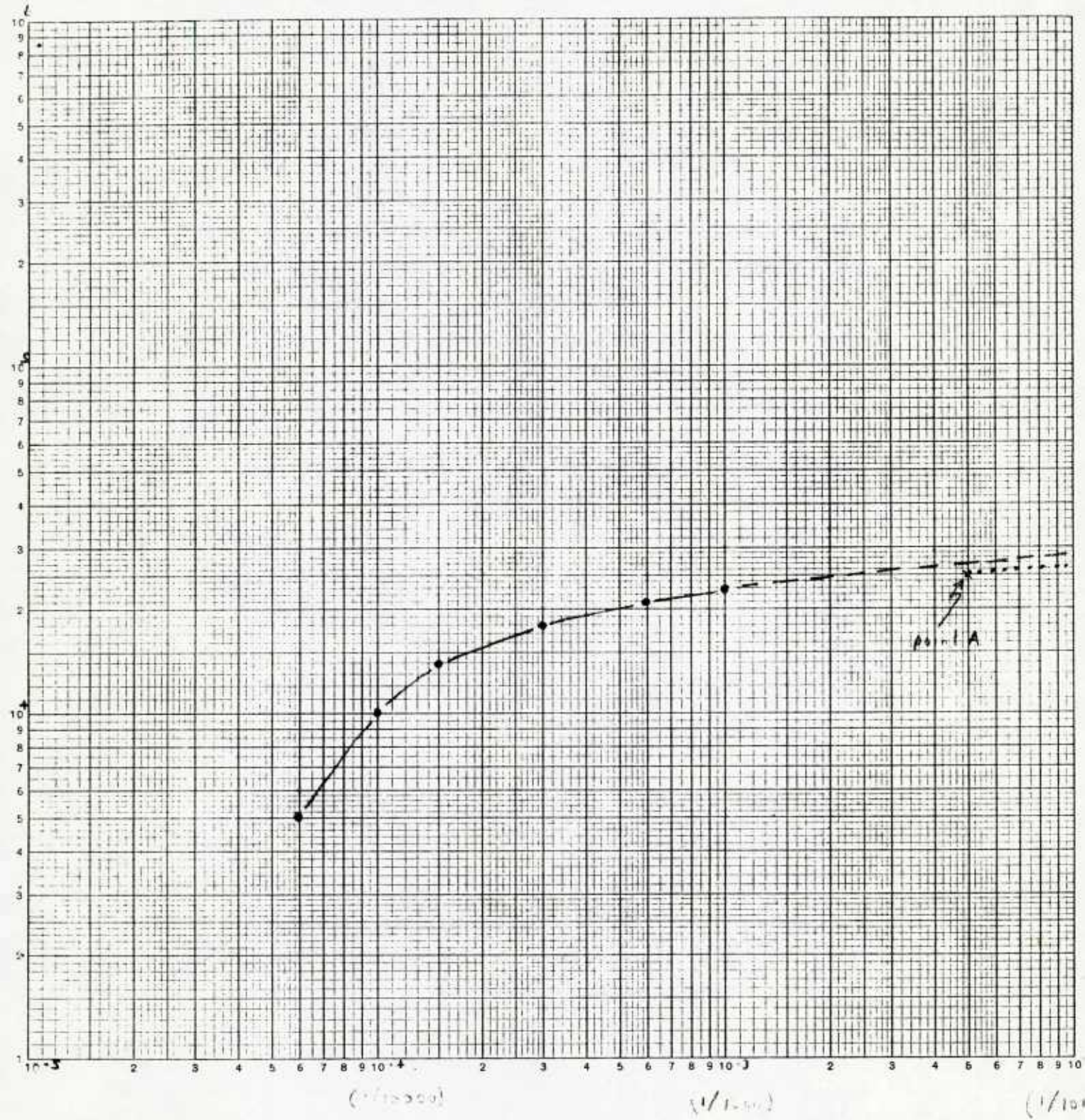
EXAMPLE

Ranked Component	MF x UP	1/(MF x UP)	Cost	Cum. Cost
#1	16667	.00006	5000	5000
#2	10000	.00010	5000	10000
#3,4	5000	.00020	2 x 2000	14000
#5,6	3333	.00030	2 x 2000	18000
#7,8,9	1667	.00060	3 x 1000	21000
#10,11,12,13	1000	.00100	4 x 500	23000

Note that several components could be ranked equally or have very close $\text{MF} \times \text{UP}$ values. Their summed data are plotted as a single point.

FIGURE 3.1: CUMULATIVE COSTS VS $1/(MF \times UP)$ ON LOG-LOG GRAPH PAPER

Cum. Cost



$1/(MF \times UP) \rightarrow$

3.2 Extrapolating

A general rule of thumb is postulated: "If the last cost data point is not within 80% of the total cost projected from an extrapolation of the curve of plotted points, more data points are required"

For example in Figure 3.1, a reasonable extrapolation (dashed line) from the 6 points yields a total cost of \$30000. However, the last point had a cumulative cost of \$23000 which is not 80% of \$30000; more components have to be "run" thru BBSIP. But if a point A (see Figure 3.1) were available, a better extrapolation (dotted line) would be to a limiting value of \$27000. Since point A is at a cumulative cost level of \$25000, which is 92.6% of \$27000, we can feel confident in stopping.

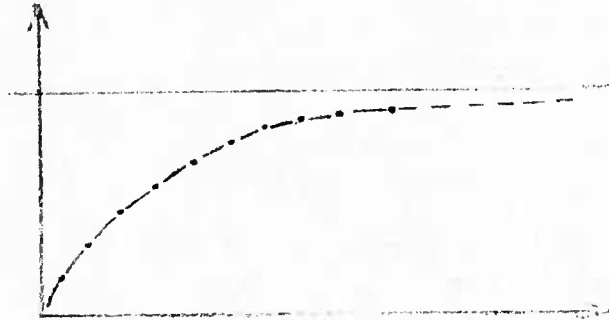
With a curve plot that is assuming a definite shape and starting to level off, extrapolation can be made by hand with an eye fit. A heuristic that by experimentation yields a reasonable extension is as follows:

- a. Subtract from the cumulative cost \mathcal{C} at the last point, the cost at $1/2$ of the value of the last $1/MF \times UP$. Call the difference d .
- b. At twice the value of $1/MF \times UP$ in (a), plot a cumulative cost $\mathcal{C}' = \mathcal{C} + \frac{2}{3} \cdot d$.
- c. At twice the value of $1/MF \times UP$ in (b), plot $\mathcal{C}'' = \mathcal{C}' + \frac{2}{3} \cdot (\frac{2}{3} d)$
- d. Continue procedure as necessary.

The 3 Cost Curve Situations

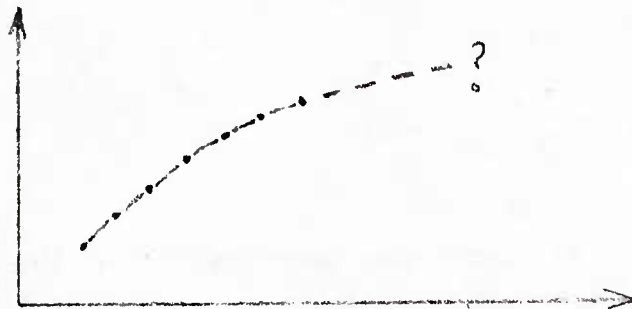
- a. All the APA components of the system are identified and estimates of some confidence are available for their parameters: In this case there is no need to plot a curve; simply sum the $Q \times UP$ values to obtain a total cost.

b. Enough APA components are available such that a cost curve can be plotted and an extrapolation can be made which approaches a horizontal level:



This case does not present any problem in projecting total cost.

c. A substantial number of APA components are available to plot a curve, but the shape is such that an extrapolation is indicated which does not level off:



In this case, a stopping rule on further extension of the extrapolation line is needed.

An auxiliary curve from the most similar system already fielded is utilized for these extension and termination decisions.

(1) Choose a similar system with all APA components and parameter values thereof identified.

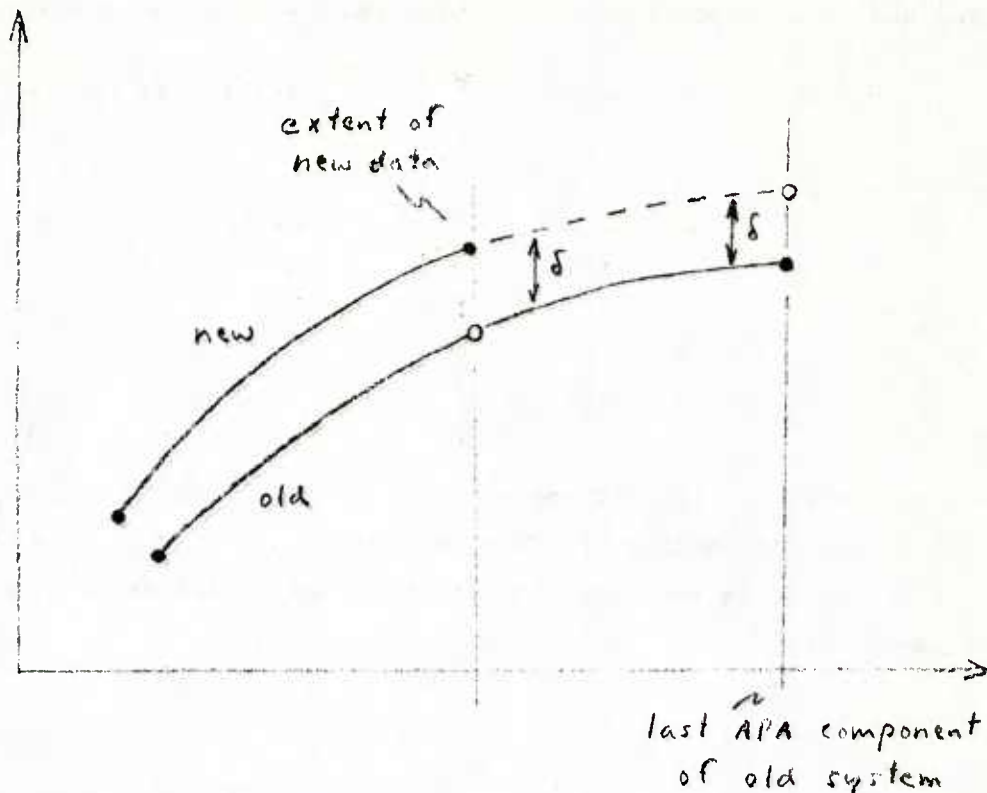
(2) Run BBSIP^{*}, with PD, M(J) adjusted to reflect new system, on enough (or all) APA components of old system to plot a curve.

(3) Plot curve of old system, terminating at the 1/MF x UP of the lowest ranked component, on same graph as partial plot of new system.

(4) Extend partial curve to termination point such that it "tracks in parallel" the old system curve.

* or SIP, when available

Figure 3.2 exemplifies graphically the above procedure



3.3 Guides to Curve Fitting

Initially Ranked Components:

a. If component #1 contributes more than 50% of the cumulative provisioning cost of all ranked components, do not plot #1. Otherwise go to step c.

b. Redefine ranking numbers: #2 \rightarrow #1, #3 \rightarrow #2, etc.

Go to step a.

c. Proceed with plotting.

Last Ranked Component:

Always draw curve thru or as close as reasonable to the last plotted point.

Outliers between first and last plotted point:

Points in the early phase of the plot which do not lie near the trend of the curve should be ignored.

Points in the later phases of the plot should have increasing influence on the final slope of the curve, but should not be forced to lie

on or very near the curve if they are clearly outliers.

Clusters of Points:

Components which have nearly equal MF x UP values are best plotted as a single point, representing the summed contribution of these components to cumulative cost, at the least MF x UP value. A single point representation is less valid if it is one of the last three points of the plot.

General Shape of Curve:

The first choice for a fit should be a completely concave curve, i.e.,



as opposed to convex (virtually impossible):



or a hybrid (possibly useful).



APPENDIX A.1

EXAMPLES

Maintenance Support Parameters

Echelon:	ORG	DS	GS	(WHOLESALE) DEPOT
V(J)	1.0	0	0	0
VSUM(J)	1.0	1.0	1.0	1.0
P(J)	0	0	0	.97
PSUM(J)	0	0	0	.97
TAT(J) (days)	1	15	30	30
OST(J) ("		5	40	40
M(J)	50	8	7	

PD = 100 U = .03 Price of End Item (UP_{NHA}) = 14000

Item A : (ERPSL) MF = 50 UP = 5500

 NON
Item B : (ERPSL) MF = 8 UP = 450

Quantity Calculations for Item A

Step d: For ORG, $R(2) = \frac{50}{100} \times (1.0-0) \times \frac{100}{50} < 6$

For DS, $R(3) = \frac{50}{100} \times (1.0-0) \times \frac{100}{8} > 6$

For GS, $R(4) = \frac{50}{100} \times (1.0-0) \times \frac{100}{7} > 6$

Go to Step f for J = 2 (since V(2) > .5)

Go to Step e for J = 3,4

Step f: $\lambda = \frac{50}{100} \times \frac{100}{50} \times 5/360 = 5/360 = .0139$

$A = 1 - \frac{5500}{14000} = .607 \rightarrow .95$

$Q'_E = \sum_{i=0}^{\infty} e^{-\lambda} \frac{\lambda^i}{i!} = .986$ for $Q'_E = 0$
 $> .95$

Step e: $Q_1(3) = Q_1(4) = 0$ since $P(J) = 0$

$$Q_2(3) = (1.0-0) \times \frac{40}{360} \times \frac{50}{100} \times 100 = 5.55$$

$$Q_2(4) = 5.55 \text{ also}$$

$$Q_{OL}(3) : (1-0) \times \frac{30}{360} \times \frac{50}{100} \times \frac{100}{8} > .5$$

$$Q_{OL}(3) = 8$$

$$Q_{OL}(04) = 7 \text{ Similarly.}$$

$$\text{Step g: } q = \frac{50}{100} \times .03 \times \frac{100}{2} = .75$$

$$\text{Depot } Q_1(5) = .97 \times \frac{30}{360} \times \frac{50}{100} \times 100 = 4.04$$

$$Q = .75 + 4.04 + 5.55 + 5.55 + 8 + 7 + 0$$

$$= 30.89 \rightarrow 31$$

Quantity Calculations for Item B

Step d: Obviously $R(J) < 6$, $J = 2, 3, 4$

Therefore no retail quantities are computed

$$\text{Step g: } q = \frac{8}{100} \times .03 \times \frac{100}{2} = .12$$

$$Q_1(5) = .97 \times \frac{30}{360} \times \frac{8}{100} \times 100 = .647$$

$$Q = .12 + .647 \approx 1$$

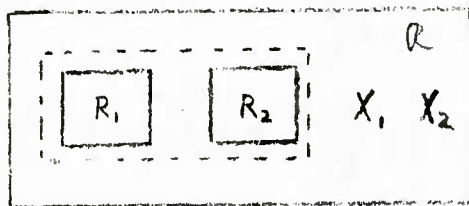
APPENDIX A.2

EXTENSIONS

A.2.1 Other Provisioning Costs (Non-APA)

The procedures in Chapters II and III can be used upon non-APA components. Plots are again made of component costs on a cumulative basis versus $1/MF \times UP$ and extrapolated. There are some differences, however, to more accurately represent the costs incurred in an actual SIP computational run over all parts in a system.

The basic unit for plotting purposes shall be the non-APA reparable; account for all component costs for that reparable, excluding other reparables within. A reparable \mathcal{R} is represented schematically:



X_1, X_2 represent piece parts (consumables) not associated with other reparables (R_1, R_2) within \mathcal{R} . The provisioning costs for \mathcal{R} consist of a "spare provisioning cost", SPC (obtained from a BBSIP run on the parameters) and a "piece-part provisioning cost" pppc (to account for X_1, X_2). The total cost $C = SPC + pppc$ is added to the previous cumulative cost and plotted vs $1/MF \times UP$ of \mathcal{R} . Only extrapolation situation (b) in Section 3.2 is relevant and the general comments for fitting a curve and extrapolating to a limiting cost level apply.

Computation of SPC: Use the logic in Section 2.2.

Computation of pppc: A new parameter $G(J)$ is defined and becomes part of the input requirement on component \mathcal{R} . $G(J)$ = total cost, on average over a year, of piece parts (consumables) needed to repair one at echelon J. $G(J)$ is normally obtained from past experience on similar

types of reparable spares. A computational alternative, if the needed parameters are available by parts X_i , is expressed by

$$G(J) = \sum_{\text{all } X_i} \frac{MF_i}{100} \cdot V_i(J) \cdot UP_i$$

However $G(J)$ is obtained, the pieceparts provisioning costs on R are found from:

$$pppc = \left[\sum_{\text{all } J} G(J) + \sum_{\text{all } J} GSUM(J) \cdot OST(J) \right] \cdot PD$$

where
$$GSUM(J) = \sum_{k=2}^J G(k)$$

Special Case: Expensive non-reparables attached to the end item or major subsystems directly, should not be incorporated into the sequence of plotting points. Their cost values should be appended to the curve-projected cost levels as a final step.

A.2.2 Computations by Area

To obtain more accuracy, the BBSIP calculations and the curve plots can be made by geographical areas (e.g. CONUS, OVERSEAS). All parameters in 2.1.2 (except UP) are then indexed by a variable A; e.g. $MF(A)$, $V(J,A)$ represent replacements per 100 end items in area A and fraction of replacements at echelon J in area A, respectively. If only some parameters can be estimated by area, computations can still be made by area, substituting single estimates of other parameters to represent averages across areas; parameters PD and $M(J)$, however, must be broken out into area values.

Cost projections are obtained separately by area and can be presented as such or summed.

APPENDIX A.3

BBSIP PROCEDURES FOR YEARLY COST OVER k YEARS

Two BBSIP Procedures for computing initial and follow-on provisioning costs over k years.

I Simpler Method

A. Compute total provisioning costs over k years

PD = ending density over k years

M(J) = total stockpoints at Jth echelon after k yrs

wholesale q (QW) = MF/100 x U x PD/2 x k

B. Allocate support to a year based on the percentage of end items deployed that year; e.g. if PD = 150

$D_2 = 15 = \text{incremental density deployed}$
in year 2

Therefore 10% or 15/150 of cost support allocated to year 2.

C. Shift yearly costs by the average PLT (of the major high dollar components) to the earlier years in which the monies for buys are to be budgeted.

II More Accurate Method

A. Compute support for initial provisioning (average PLT + 3 mos = PFP)

PD = density in PFP

M(J) = stockpoints at Jth echelon in PFP

B. Compute cost support for follow-on provisioning in yearly increments for remaining years (one BBSIP for each year)

PD = additional density deployed in that year

M(J) = additional stockpoints in that year

Additional wholesale quantity (added to $\frac{MF}{100} \times U \times \frac{PD}{2}$):

$$q' = \frac{MF}{100} \times U \times BD$$

BD = beginning density prior to that year

- C. For PFP greater than 1 year, allocate cost support by year as in I.B.
- D. Shift yearly costs as in I.C.

APPENDIX A.4

FORTRAN PROGRAM
TO COMPUTE PBFP QUANTITIES

```

COMMON/SYST/RSC, ESS, PD, M(6), YR, JJ
COMMON/PART/NSN, RF, U, UP, UPNHA, V(6), P(6), TAT(6), OST(6)
COMMON/GENRL/VSUM(6), PSUM(6), QW, Q1(6), Q2(6), QOL(6), QE(6), Q
ACCEPT N, RSC, ESS, PD, JJ
DO 100 ITEM=1, N
ACCEPT NSN, RF, U, UP, UPNHA
ACCEPT ((V(K), P(K), TAT(K)), K=2, JJ)
ACCEPT ((M(K), OST(K)), K=2, JJ-1)
CALL QTY
RANK=1./(RF*UP)
COST=Q*UP
DISPLAY ITEM, NSN, Q, UP, RANK, COST
100 CONTINUE
STOP
END

```

} FORMAT OWN
} READ & WRITE STATEMENTS.

```

SUBROUTINE QTY
COMMON/SYST/RSC, ESS, PD, M(6), YR, JJ
COMMON/PART/NSN, RF, U, UP, UPNHA, V(6), P(6), TAT(6), OST(6)
COMMON/GENRL/VSUM(6), PSUM(6), QW, Q1(6), Q2(6), QOL(6), QE(6), Q
DIMENSION R(6)
YR=365.
VSUM(1)=PSUM(1)=Q=0.
DO 10 J=2, JJ
VSUM(J)=VSUM(J-1)+V(J)
PSUM(J)=PSUM(J-1)+P(J)
10 Q1(J)=Q2(J)=QOL(J)=QE(J)=0.
DO 15 J=2, JJ-1
R(J)=(RF/100.)*(VSUM(J)-PSUM(J-1))*(PD/M(J))
IF(ESS.EQ.1.0.AND.V(J).GE..5)CALL ERPSL(J)
IF(ESS.EQ.1..AND.V(J).LT..5)CALL PIPE(J)
15 IF(R(J).GE.RSC.AND.ESS.EQ.0.)CALL PIPE(J)
QW=(RF/100.)*U*PD/2.
Q1(JJ)=P(JJ)*(TAT(JJ)/YR)*PD*RF/100.
DO 20 J=2, JJ-1
Q=Q+Q1(J)+Q2(J)+QOL(J)+QE(J)
20 CONTINUE
Q=Q+QW+Q1(JJ)
RETURN

```

[* k for k-year runs]

Refer to guide for notation & logic.

Code key to additional parameters on next page.


```

SUBROUTINE PIPE(J)
COMMON/SYST/RSC, ESS, PD, M(6), YR, JJ
COMMON/PART/NSN, RF, U, UP, UPNHA, V(6), P(6), TAT(6), OST(6)
COMMON/GEVRL/VSUM(6), PSUM(6), QW, Q1(6), Q2(6), QOL(6), QE(6), Q
Q1(J)=P(J)*(TAT(J)/YR)*PD*RF/100.
Q2(J)=(VSUM(J)-PSUM(J))*(OST(J)/YR)*PD*RF/100.
TEMP=(VSUM(J)-PSUM(J))*(30/YR)*(PD/M(J))*RF/100.
IF(TEMP.GT.0.5)QOL(J)=M(J)
RETURN
END
SUBROUTINE ERPSL(J)
COMMON/SYST/RSC, ESS, PD, M(6), YR, JJ
COMMON/PART/NSN, RF, U, UP, UPNHA, V(6), P(6), TAT(6), OST(6)
COMMON/GEVRL/VSUM(6), PSUM(6), QW, Q1(6), Q2(6), QOL(6), QE(6), Q
IF(ESS.EQ.0.)RETURN
FD=(RF/100.)*(PD/M(J))*((VSUM(J)-PSUM(J))*OST(J)+P(J)*TAT(J))/YR
A=1.-UP/UPNHA
IF(A.GT..99)A=.99
IF(A.LT..95)A=.95
EFD=EXP(-FD)
I=0
IF(EFD.GT.A)GO TO 10
SUM=1.
IFAC=1
DO 5 I=1,10
IFAC=I*IFAC
SUM=SUM+(FD*I)/IFAC
IF(SUM*EFD.GT.A)GO TO 10
5 CONTINUE
I=10
QE(J)=I*M(J)
RETURN
END

```

Code

Explanation Key

JJ

Number echelons (6 or less)

ESS

System/end item qualifies for an

ERPSL; ESS=1. Otherwise ESS=0
(see *** in sec 2.2 for current ESS=1 parts)

RSC

Retail Stockage Criteria (6 is used in guide)

QW

Wholesale quantity (:= 3 in guide)

RF

Maintenance Factor (used MF in guide)

NSN

NSN of component

N

Number of components in this run.

APPENDIX A.5

TEST RESULTS

The Bare-Bones SIP approach was tested on two end items at Electronics Command, Fort Monmouth, NJ. One system, the TRN-30 Radio Beacon, was chosen because parameter estimates for all its components were currently loaded in the Provisioning Master Data Record. The purpose was to investigate: the behavior of a typical cost curve, plotting procedures, ranking measures, and extrapolation from initially ranked components where any percentage of the total components can be made available.

The second system, the TD-976 Asynchronous Digital Combiner, was chosen to represent situations where preliminary data is available on only a small percentage of the components. We wished to determine, from a typical Project Manager's Office, the availability, extent and usefulness of data to make reasonable first projection early on in the development cycle. Parameter estimates on 13 critical subsystems were available.

Figure A.4.1 shows a curve fit to the first 34 components (ranked by MF x UP) of the TRN-30 on log-log paper. The table shows how the extrapolation improved when 106 components were used instead of 34. Nevertheless, with $\frac{34}{1900} = 1.8\%$ of components, the projection \$130,000 differs from \$147,000 by only 11.5%. Note that the provisioning cost of the first module was quite large and was omitted from the plotting procedure.

Figure A.4.2 indicates that the available subsystems of the TD976 can give a reasonable plot and extrapolation. Again the first ranked module had very high cost and was best appended at the end of the plotting procedure.

Figure A.4.1 TRN - 30 Cost Curve / 100 Beacons

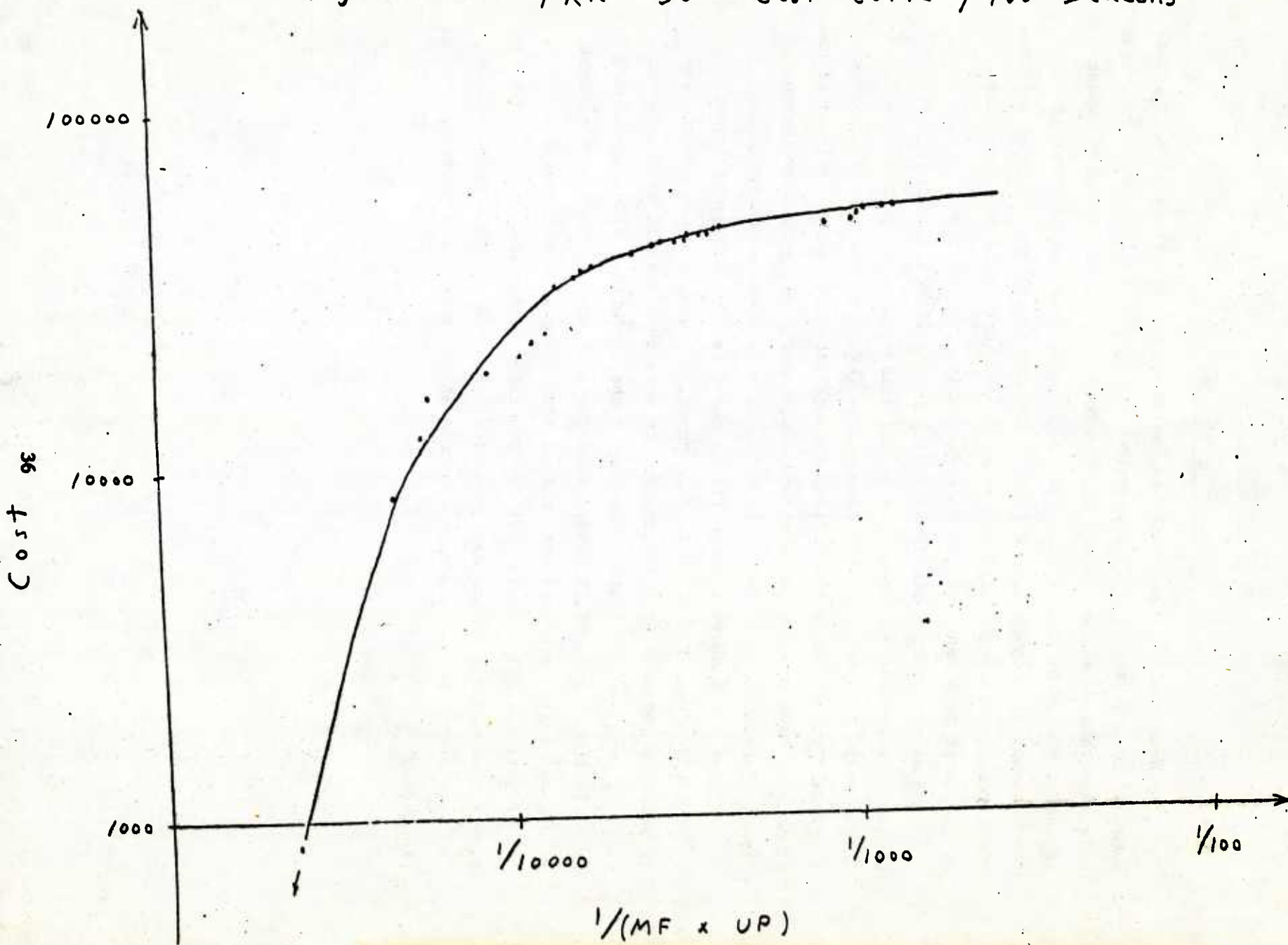
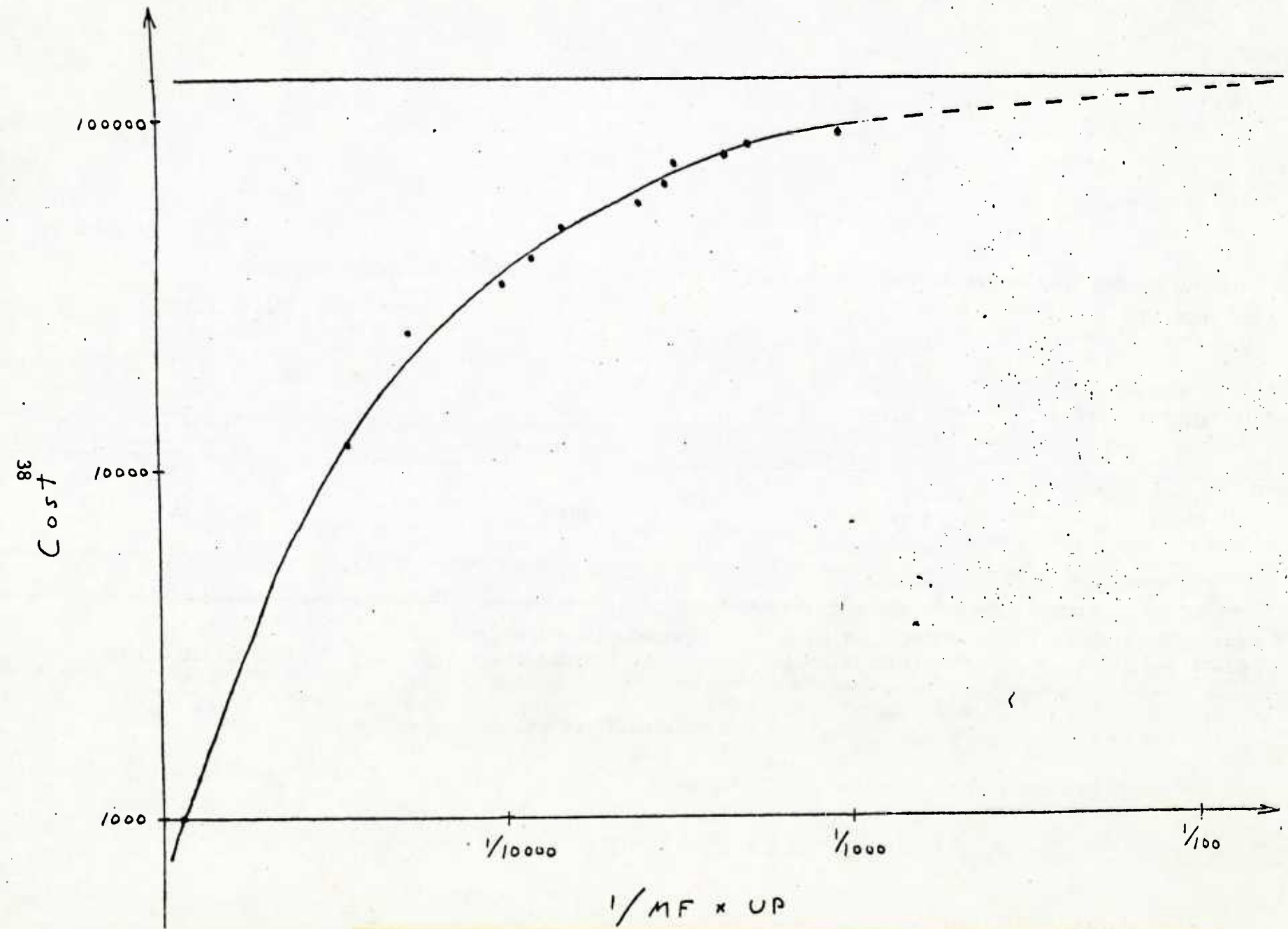


Table A.5

TRN-30 RADIO BEACON

NUMBER OF ITEMS USED	BBSIP PROJECTIONS (EXCLUDING 1ST MODULE)	PROVISIONING COST OF 1ST MODULE	TOTAL PROJECTED PROVISIONING COST
34	60000	69776	130000
106	72000	69776	142000
All (1900)			147000

Figure A.4.2 TD 976 Cost Curve



Calculator* Version of ERPSL Computation

Compute λ, A

<u>i</u>	<u>Keys</u>	<u>STOP?</u>
0	$\text{EXP}(-\lambda) \rightarrow m_1$ $1 \rightarrow \text{sum}$	$m_1 \times \text{sum} > A? \Rightarrow Q_E = 0$
1	$\lambda \rightarrow m_2$ $\text{sum} \leftarrow \text{sum} + m_2$	$m_1 \times \text{sum} > A? \Rightarrow Q_E = 1 \times M$
2	$m_2 \leftarrow m_2 \times \frac{\lambda}{2}$ $\text{sum} \leftarrow \text{sum} + m_2$	$m_1 \times \text{sum} > A? \Rightarrow Q_E = 2 \times M$
3	$m_2 \leftarrow m_2 \times \frac{\lambda}{3}$ $\text{sum} \leftarrow \text{sum} + m_2$	$m_1 \times \text{sum} > A? \Rightarrow Q_E = 3 \times M$

* Two memories m_1, m_2 ("sum" memory can be done on paper if necessary)

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